STUDY ON TRACE METALS IN BIO MATERIALS

II. Cadmium Content in Polished Rice*

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In this paper, the analytical results on cadmium of rice, which is the staple food of the Japanese, are described. There are observed three general trends for the cadmium content of rice samples. First, the local difference of cadmium content of polished rice is remarkable. Secondly, the difference of cadmium content among varieties is small as compared with the local difference. Thirdly, the cadmium content of the bran layer is higher than that of the endosperm, although the difference is not so remarkable as in the content of other inorganic elements.

Nicaud et al. (1942) and others (Baader 1951, Friberg 1959, Piscator 1962) have clarified that the chronic or acute cadmium intoxication occurs in alkaline battery factories with the symptoms of bone trouble, kidney damage and excretion of proteinuria. Furthermore, several workers (Perry et al. 1961, Schroeder and Balassa 1961), in their analytical investigations on human tissues, have demonstrated that a considerable amount of cadmium is present in kidney as compared with other tissues, and its content in human tissues increases progressively with age. In addition, their analytical results have indicated that the cadmium content of the Japanese belongs to high group in the world. It is therefore of importance to investigate the cadmium content of the staple food of the Japanese.

We have found that cadmium is present in various agricultural products and waters (unpublished data), and as described in the former report (1962), even 'ayu' in Japanese or *plecoglossus altivelis*, one of the river fish, contains cadmium in detectable amount.

Preparation of Rice Samples

As shown in Fig. 1, about 200 samples of rice were collected from various prefectural agricultural experiment stations. The other samples were cooperatively offered from the Tokyo Food Office of Ministry of Agriculture and Forestry, U. S. Rice Experiment Station in Luisianna and others.

The samples were polished to the uniform degree by a test cleaning machine until the weight of polished rice decreased to 90 percent of unpolished rice, except for the ones previously polished. (The unpolished rice is prepared by removing the hulls from the rough rice)

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Fig. 1. Sampling places of Japanese rice which was sent from various prefectural agricltural experiment stations

The number in this chart is the same as the number of agricultural experiment stations in table 1. And star mark expresses the situation of each agricultural experiment station.

Method of Analysis

The analysis was carried out on 20 grams of polished rice. The sample, which had been taken in a ceramic crucible, was ignited overnight in the electric muffle furnace at 475°C. Next day, 1 *ml* of 10 percent solution of sodium sulfate and the same volume of concentrated nitric acid was added to hasten the oxidation of residual carbon. The mixture in the crucible was heated quietly on a sand bath until nitric fumes disappeared and then placed in the muffle furnace, set at 350° to 450°C, for 10 to 20 minutes. A trace of carbon which was still remaining was removed by the repetition of nitric acid treatment followed by muffle ignition. Thus, the carbon-free ash was obtained within 2.5 *ml* of nitric acid added.

The final ash, peachblow coloured, was analyzed by the colorimetric method of Saltzman (1953), slightly modified. In order to prevent the interference of considerable amounts of magnesium derived from the initial sample, the volume of sodium-potassium tartrate solution was always increased from 1 *ml* in the original method to 5 *ml* (Moritsugu 1964). Especially, in the analysis of unpolished rice, it was essential to use a large amount of sodium-potassium tartrate, because unpolished rice contained more magnesium than polished rice. As described above, sodium sulfate solution was also added to accelerate ashing.

In addition, thallium separation was not carried out, because the spectral line of thallium was invisible nevertheless the spectral line of cadmium was distinctly visible on the plates which are the results of the spectrochemical analyses of the ashes of rice samples.

ANALYTICAL RESULTS

1. *Local Difference of Cadmium Content*

The cadmium content of samples from the various agricultural experiment stations shows a great difference as can be seen in Table 1 and Fig. 2.

TABLE 1

Cadmium content of Japanese rice

Name of experiment station	Variety name	Classification by growing period	Cadmium content ($\mu g/kg$)	Name of experiment station	Variety name	Classification by growing period	Cadmium content ($\mu g/kg$)
1. Hokkaido	Norin 34	e	19	2. Aomori	Norin 17	l	19
	Fukuyuki	e	20		Fujisaka 5	m	14
	Eiko	m	33		Mutsuhikari	m	15
	Mimasari	m	15		Towada	m	12
	Terunishiki	l	12		Aomori-mochi 14	m	19
	Toyohikari	l	15		Average		16
	Average		19				
3. Iwate	Norin 17	m	24	4. Miyagi	Norin 16	m	16
	Fujisaka 5	e	26		Norin 17	m	13
	Rikuu 132	m	31		Norin 24	m	16
	Sasashigure	l	25		Fujisaka 5	e	14
	Chokai	m	16		Shin 6	—	17
	Average		24		Sasashigure	m	15
					Average		15

TABLE 1 continued

5. Akita	Norin 17	m	85
	Norin 41	l	78
	Hatsunishiki	e	36
	Chokai	m	71
	Towada	e	61
	Average		66
6. Yamagata	Norin 17	m	46
	Norin 41	m	42
	Fujisaka 5	e	131
	Sasashigure	l	51
	Ginmasari	l	106
	Average		75
7. Fukushima	Norin 21	m	16
	Fujisaka 5	e	22
	Sasashigure	m	21
	Akibae	m	9
	Sekiminori	m	15
	Average		17
8. Ibaragi	Norin 1	e	87
	Norin 14	e	228
	Norin 29	l	131
	Tone-wase	e	113
	Koshihikari	e	182
	Average		148
9. Tochigi	Norin 10	m	26
	Norin 16	e	17
	Norin 24	e	16
	Norin 29	m	22
	Norin 48	m	34
	Average		23
10. Gunma	Norin 24	m	31
	Norin 25	l	22
	Norin 25	l	1195*
	Norin 25	l	310*
	Norin 29	m	30
	Norin 48	m	30
	Chiba-asahi	l	69
	Saitama-mochi	e	34
	Average		36
11. Chiba	Mixed	—	52
12. Tokyo	Norin 17	e	160
	Tozan 38	l	472
	Yashima-senbon	l	421
	Tone-wase	e	89
	Yamabiko	m	174
	Average		263
13. Kanagawa	Norin 8	m	19
	Norin 23	m	30
	Norin 29	e	19
	Norin 32	e	29
	Yamabiko	m	27
	Average		25
14. Niigata	Yoneyama	—	140
	Nihonkai	—	30
	Koshiji-wase	e	24
	Koshisakae	—	44
	Koshihikari	m	53
	Average		58
15. Toyama	Sanin 17	l	413
	Shinmasari	—	128
	Honen-wase	e	47
	Shirogane	m	167
	Average		189
16. Ishikawa	Sanin 17	l	258
	Haya-norin	e	72
	Koshiji-wase	e	97
	Honen-wase	e	74
	Yomohikari	—	130
	Average		126
17. Fukui	Norin 23	l	75
	Norin 30	e	113
	Honen-wase	e	100
	Manryo	—	317
	Fukuminori	m	153
	Average		152
18. Yamanashi	Norin 22	l	36
	Norin 31	l	30
	Kinmaze	l	31
	Wakaba	m	6
	Yamabiko	—	7
	Average		22
19. Nagano	Norin 10	l	9
	Norin 17	m	34
	Akibae	m	34
	Yomohikari	—	100
	Chikuma	l	132
	Average		62
20. Shizuoka	Aichi-asahi	m	30
	Shimotsuki	l	55
	Mihonishiki	m	21
	Yaeho	e	30
	Hamayu	—	31
	Average		33
21. Aichi	Norin 17	e	24
	Tokai-senbon	l	21
	Kinmaze	m	14
	Shin-yamabuki	—	21
	Hatsushimo	m	17
	Mihonishiki	l	19
	Average		19
22. Mie	Norin 22	e	35
	Norin 29	e	53
	Toyosenbon	l	104
	Koganenishiki	m	51
	Mihonishiki	l	86
	Average		66

* Yielded from test field of mine-affected area, leaved out from average account.

TABLE 1 continued

23. Shiga	Norin 29	e	132	24. Kyoto	Norin 17	e	22
	Shin-yamabuki	—	57		Asahi 4	m	41
	Average		95		Nakate-shinsenbon	—	14
					Kinmaze	l	42
					Akebono	l	62
					Average		36
25. Hyogo	Norin 17	e	151	26. Nara	Tokai-asahi	l	129
	Norin 22	e	12		Shin-kinmaze	—	54
	Norin 23	e	17		Akebono	l	82
	Asahi	l	11		Koganenishiki	e	121
	Senbon-asahi	l	9		Asahi-mochi	l	173
	Kinmaze	m	15		Average		112
	Mihonishiki	l	12				
	Ukonnishiki	e	10				
	Average		30				
27. Wakayama	Norin 22	e	14	28. Tottori	Norin 22	m	93
	Norin 37	m	5		Norin 29	m	61
	Kinmaze	m	9		Shuho	e	18
	Hatsushimo	m	15		Takane	m	55
	Koganenishiki	e	7		Hoki-asahi	m	103
	Average		10		Yamabiko	m	57
					Yaeho	l	100
					Tsubasa	l	123
					Average		76
29. Shimane	Norin 22	m	83	30. Okayama	Norin 22	e	81
	Kinki 33	e	16		Asahi	l	122
	Mihonishiki	l	91		Akebono	l	33
	Takane	m	12		Mihonishiki	l	106
	Yaeho	m	43		Koganenami	e	88
	Average		49		Average		86
31. Hiroshima	Norin 17	e	33	32. Yamaguchi	Norin 12	l	130
	Norin 22	m	61		Norin 17	e	19
	Nakate-shinsenbon	m	82		Norin 37	m	58
	Koganenami	m	50		Hikari	l	113
	Chiyohikari	m	29		Takane	m	100
	Average		51		Average		84
33. Tokushima	Norin 8	e	129	34. Kagawa	Tozan 38	e	40
	Norin 17	e	20		Kagawa 35	l	96
	Akebono	m	20		Akebono	l	109
	Mihonishiki	m	155		Mihonishiki	m	81
	Sachiwatari	e	26		Shioji	l	32
	Average		70		Average		72
35. Ehime	Norin 22	e	153	36. Kochi	Norin 22	m	31
	Matsuyama-mitsui	l	211		Tosa 2	l	35
	Akebono	l	333		Koshiji-wase	e	12
	Mihonishiki	m	176		Honen-wase	e	63
	Average		218		Sachiwatari	m	62
					Average		41
37. Fukuoka	Norin 18	l	16	38. Saga	Imari 1	l	111
	Norin 22	e	75		Hozakae	l	38
	Jikkoku	—	44		Benisengoku	l	17
	Ayanishiki	e	16		Average		55
	Towada	e	108				
	Average		52				
39. Nagasaki	Norin 18	l	65	40. Kumamoto	Norin 12	l	25
	Norin 22	e	74		Norin 18	l	28
	Shinai	l	55		Takara	l	31
	Shimotsuki	l	60		Hosaku	l	30
	Average		64		Higo-mochi	l	26
					Average		28

TABLE 1 continued

41. Oita	Norin 17	e	22	Japanese average	66
	Norin 18	l	120		
	Norin 22	e	109		
	Oita-mitsui	l	19		
	Hozakae	l	59		
	Average		66		

Cadmium content was expressed as micrograms of cadmium per kilogram of polished rice, kept in an air dried condition at room temperature.

The terms of early rice (e), mid-season rice (m) and late rice (l) were from N. G. K. (1957) and N. K. K. (1955). (— Classification unknown)

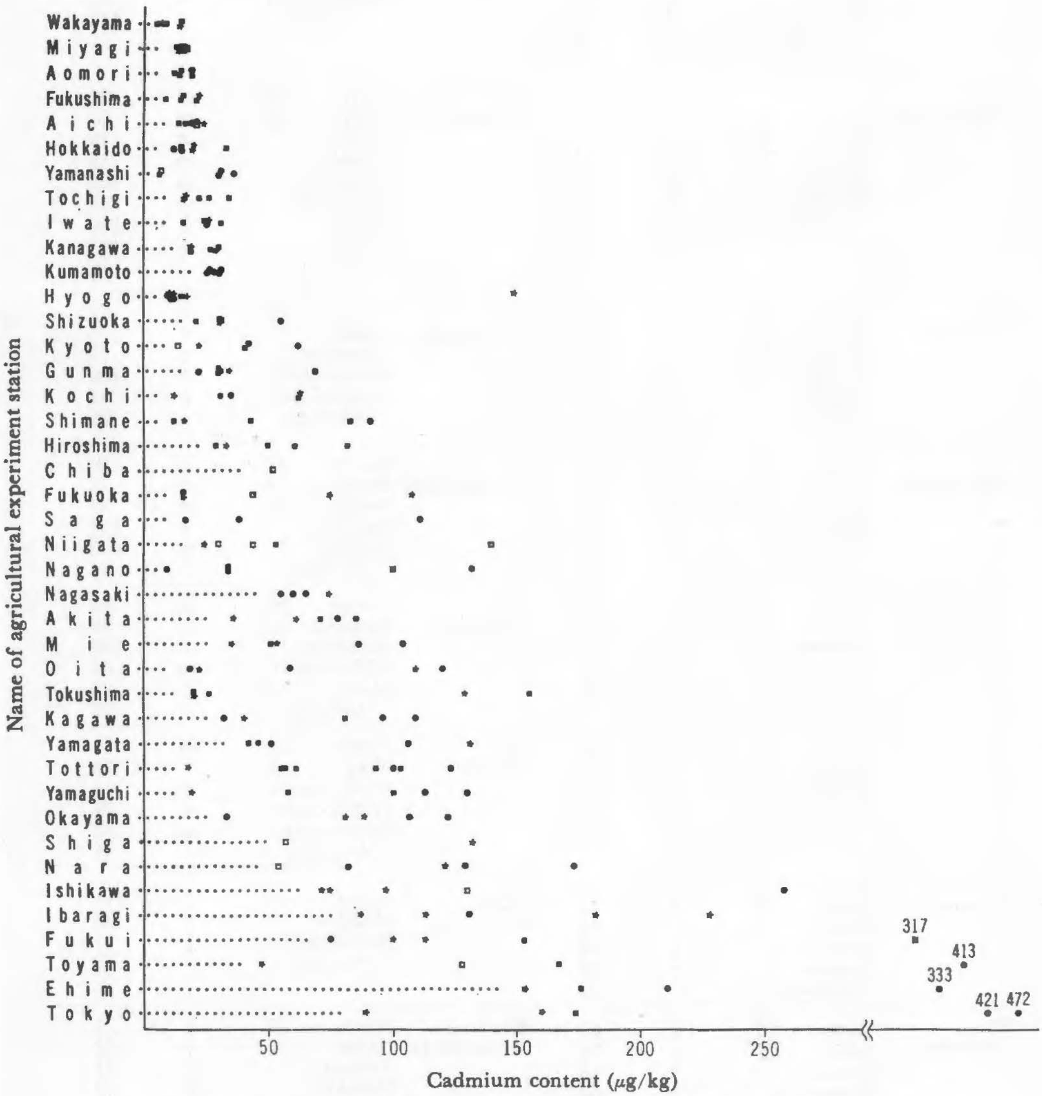

Fig. 2. Cadmium content of rice sent from various agricultural experiment stations.
★ Early rice ■ Mid-season rice ● Late rice □ Classification unknown

The highest cadmium content of 1195 μg/kg, or about 1.2 ppm, is found in a sample obtained from the test field of zinc-poisoned area in Gunma Prefecture. The second cadmium content is seen in samples sent from Tokyo agricultural experiment station (472 and 421 μg/kg) and Toyama agricultural experiment station (413 μg/kg), while the lowest cadmium content of 5 μg/kg is seen in a sample obtained from Wakayama agricultural experiment station. In addition, the samples from the Yamanashi agricultural experiment station, 6 μg/kg and 7 μg/kg, that from the Wakayama agricultural experiment station, 7 μg/kg, and those from Fukushima, Nagano and Hyogo agricultural experiment stations, 9 μg/kg respectively, belong to low group.

Judging from the average for the samples from each experiment station, those from Tokyo, Toyama and Fukui experiment station belong to high group; the average being respectively 218, 189 and 151 μg/kg. On the contrary, low average content is seen in the samples from the following agricultural experiment stations: Wakayama, Miyagi, Aomori, Fukushima, Aichi and Hokkaido; the average, respectively 10, 15, 16, 17, 19 and 19 μg/kg.

Except for mine-affected rice, average cadmium content of 203 Japanese rice samples is 66 μg/kg (0.066 ppm) with 5.0 μg/kg of standard error.

As mentioned above, the cadmium content varies widely according to localities. But, the reason why the local difference occurred in the cadmium content is unknown, because the relation between the cadmium content and the environmental factors, such as geological origin of soil, soil texture, soil reaction, method of cultivation, yield per unit area and nature of irrigation water, is uncertain.

From the analytical result of foreign rice shown in Table 2, it is observed that the cadmium content is generally low, except for Mississippi rice.

The cadmium content of mine-affected rice is shown in Table 3. The samples are collected from the following areas; 1) the Jintsu river basin in Toyama Prefecture which is the lower reaches of Kamioka mine where the main products are zinc and lead (A wide and severe damage from Kamioka mine polution had been observed during the Second World War, although the damage was progressively decreasing.), 2) the Usui river basin in Gunma Prefecture which is the lower reaches of Annaka refinery where zinc is mainly refined (zinc-poisoned district at present), 3) the Watarase river basin in Gunma Prefecture which is the lower reaches of Ashio copper mine (copper-poisoned district at present). While, as the controles of the above mine-affected areas, the samples are also collected from the following areas; 1') the basin of Ida river which is a tributary of the Jintsu river, 3') an area in the Watarase river basin where crops are not damaged by copper polution, although this area is also irrigated by the Watarase river, 3'') the new developed paddy field of non-Watarase basin in the neighbourhood of the Watarase river.

As shown in Table 3, the rice samples, which are obtained from the lower

TABLE 2
Cadmium content of foreign rice.

Countries	Grain form	Cadmium content (μg/kg)	Remarks
Formosa	short	38	purchased from a rice shop in Kurashiki city
	short	53	sent from Okayama Food Office
			sent from Tokyo Food Office
	short	31	Polished at Taipei Rice Mill
	short	70	Polished at Taoyuwan-chên Rice Mill
	short	62	Polished at Shinchue Rice Mill
	short	66	Polished at Taichon Rice Mill
	short	38	Polished at Homei-chên Rice Mill
	short	8	unknown
Thailand	long	19	
Burma	long	16	
	long	13	
Egypt	short	14	
Spain	short	49	
U. S. A.			sent from U. S. Rice Experiment Station
	long	156	Stonville Miss. Bluebonnet 50
	long	139	4-11-1-8 × RC-252
	medium	93	Zenith
	medium	110	Nato
	long	16	Stuttgart Ark. Variety Bluebonnet
	long	10	Variety 4-11-1-8 × RC-252
	medium	16	Variety Zenith
	medium	14	Variety Nato
	long	6	Beaumont Tex. 425 Bluebonnet
	long	32	21 4-11-1-8 × RC-252
	medium	20	405 Zenith
	medium	25	402 Nato
	long	10	Crowly La. Bluebonnet 50, 257
	long	10	4-11-1-8 × RC-252, 240
	medium	6	Zenith, 234
	medium	12	Nato, 231

reaches of the mine station where zinc and lead are mainly treated, contain a considerable amount of cadmium. In addition, the rice samples, obtained from the copper-affected areas, namely 3) and 3′), contain more cadmium than normal rice. In consequence, it is likely that the cadmium content of rice from the lower reaches of mine station is generally high independent of the kind of metals produced.

TABLE 3
Cadmium content of mine-affected rice

	Producing districts	Variety name	Cadmium content ($\mu g/kg$)
1.	Jintsu river basin in Toyama Prefecture	—	580
		—	1202
		Kinmaze	257
		Shinki 2	495
		—	730
		Kurobe 1	825
		Taisho-mochi	912
		Taisho-mochi	1025
		—	446
		—	458
		Shinki 2	804
		—	441
		Wakaba 4	443
		Kinmaze	412
		Taisho-mochi	896
		Kurobe 1	532
		Kurpbe 1	398
		—	582
		—	1623
		—	600
1'.	Ida river basin in Toyama Prefecture	—	296
		Fuko 8	64
		Kinmaze	161
		Kinmaze	125
		Shinki 2	190
		—	72
2.	Usui river basin in Gunma Prefecture	Norin 25	1195
		Asahi	267
		Norin 25	113
		Norin 29	446
		Norin 29	328
		Kinmaze	356
		Kinmaze	217
		Norin 29	225
3.	Watarase river basin in Gunma Prefecture (mine-poisoned)	Norin 25	258
		Norin 48	223
		Norin 25	221
		Norin 25	310
		—	193
		—	237
		—	259
3'.	Not poisoned area in Watarase river basin	—	104
		—	312
3''.	Non-Watarase basin nearby above area	—	44
		—	80

2. *Difference of Cadmium Content among Varieties*

The relationship between the cadmium content and the length of growing period, classified into three groups, was investigated. As shown in Table 4, the following order of the cadmium content was obtained with the samples of the 8 agricultural experiment stations, namely Tochigi, Tokyo, Toyama, Ishikawa, Mie, Tottori, Yamaguchi and Ehime: late rice>mid-season rice>early

TABLE 4
Relationship between cadmium content of polished rice and growing period

Order of cadmium content among rice varieties	Number of examples	Name of experiment station concerned
early rice>(mid-season rice)>late rice	1	Nagasaki
late rice>mid-season rice>early rice	8	Tochigi, Tokyo, Toyama, Ishikawa, Mie, Tottori, Yamaguchi, Ehime.
No distinct tendency	32	Other 32 experiment stations

rice. In addition, the cadmium content from these stations is generally higher than the Japanese average of 66 μg/kg, except for those from Tochigi. With the samples of Nagasaki agricultural experiment station, opposite order was found imperfectly, as follows: early rice> late rice. There was observed no general trend in the other cases. Furthermore, in the foreign rice, the difference of grain form namely the difference of type of rice has no relation with the cadmium content as shown in Table 2.

Consequently, it is likely that the difference of cadmium content among varieties is less than the local difference.

3. *Distribution of Cadmium in Rice Grain*

In this experiment, owing to the analytical sensitivity, the rice samples of high cadmium content were used which were obtained from the Jintsu river basin in Toyama Prefecture. And, cadmium determination was carried out on the following samples; the unpolished rice (prepared from the rough rice by removing the hulls), the polished rice (prepared from the unpolished rice through the course of rice polishing by removing the rice bran equivalent to 10 percent of unpolished rice, namely most of the endosperm), the rice bran (the byproduct of rice polishing, namely bran layer, including the embryo buds and the outer part of endosperm) and the embryo bud (purified by screaning from the rice bran).

As shown in Table 5, it is clear that the rice bran and the embryo bud contain a considerable amount of cadmium that is equivalent to 2 to 4 times of cadmium in the polished rice. However, the cadmium content of the polished rices is equal to 90 percent or more of that of unpolished rices.

As expected from the results in Table 5, the cadmium content decreases

TABLE 5
Cadmium content of unpolished rice, polished rice, rice bran and embryo

Variety name	Cadmium content (μg/kg)			
	Unpolised rice	Polished* rice	Rice bran	Embryo
Taisho-mochi	1055	1025	——	2138
——	630	582	1234**	2357
Kurobe 1	443	398	1080***	2076

Samples were obtained from Jintsu river basin in Toyama Prefecture.
* Polished rice, prepared from unpolished rice by removing 10% bran.
** Rice bran from which embryo was eliminated.
*** Rice bran which contains embryo.

TABLE 6
Decreasing rate of cadmium content and ash content during rice polishing

Taisho-mochi (Variety name)	Degree of polishing*	(%)	0	2.3	6.3	12	26	36	
	Ash content	(%)	1.42	1.10	0.96	0.71	0.38	0.37	
	Decreasing rate** of ash content	(%)	100	77	68	50	27	26	
	Cadmium content	(μg/kg)	1055	1050	1040	1015	945	940	
	Decreasing rate of** cadmium content	(%)	100	100	99	96	90	89	
Kurobe 1	Degree of polishing*	(%)	0	3.2	6.4	10	22	30	40
	Ash content	(%)	1.28	1.04	0.91	0.70	0.34	0.26	0.23
	Decreasing rate** of ash content	(%)	100	81	71	55	27	20	18
	Cadmium content	(μg/kg)	443	435	423	398	385	368	350
	Decreasing rate of** cadmium content	(%)	100	98	95	90	87	83	79

Samples were obtained from Jintsu river basin in Toyama Prefecture.
* Expressed as percentage of rice bran rubbed off from unpolished rice.
** Expressed as percentage of content in polished rice to that in unpolished rice.

inversely to the rice polishing (Table 6). But, the decreasing rate of cadmium content during the course of rice polishing is rather small. Furthermore, the content of cadmium decreases at a lower rate than that of ash or inorganic elements other than cadmium, because there is a marked difference between the polished rice and the rice bran, with respect to mineral composition. Accordingly, the ratio of content of cadmium to that of ash, namely cadmium content in the ash, increases rapidly during the course of rice polishing. As shown in Fig. 3, the increase of cadmium content in the ash is more rapid than those of copper and manganese which showed the most rapid increases among the elements

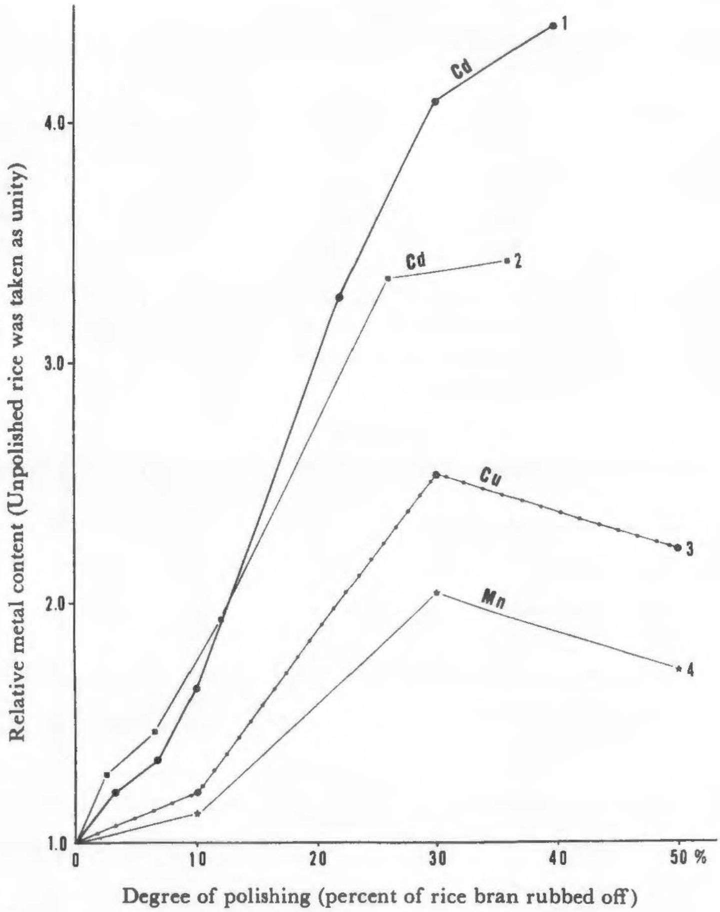

Fig. 3. Increase of metal content during rice polishing.
1. Kurobe 1, obtained from Jintsu river basin in Toyama Prefecture, cadmium content in ash of unpolished rice, 35 ppm.
2. Taisho-mochi, obtained from Jintsu river basin in Toyama Prefecture, cadmium content in ash of unpolished rice, 74 ppm.
3 and 4. Asahi, cited from analytical results by Katakura and Hatanaka (1953), copper and manganess content in unpolished rice, 291 and 1782 ppm each.

analyzed by Katakura and Hatanaka (1959).

Consequently, it may be concluded that the ash of polished rice contains more cadmium than that of unpolished rice, although the cadmium content of rice bran is higher than that of the polished rice like other inorganic elements. In other words, cadmium distribution in the rice grain is more homogeneous as compared with other elements.

SUMMARY

The cadmium content of about 250 rice samples, most of which were

obtained in Japan, were determined by the method of Saltzman, slightly modified.

The cadmium content of polished rice showed a remarkable difference according to the producing area. Excepting mine-affected rice, the cadmium content of Japanese rice came to between the maximum limit of 472 μg/kg and the minimum of 5 μg/kg, and the average was 66 μg/kg, wheras, the cadmium content of foreign rice came to between the maximum limit of 156 μg/kg and the minimum of 6 μg/kg. Consequently, the cadmium content of Japanese rice appeared to be high as compared with that of the foreign rice.

The cadmium content of mine-affected rice was higher than that of the normal rice. In the Jintsu river basin in Toyama Prefecture which is the lower reaches of Kamioka mine where zinc and lead are mainly produced, the cadmium content of the polished rice reached to 1600 μg/kg in maximum, in the lower reaches of the Usui river in Gunma Prefecture which is affected by Annaka refinery, the maximum cadmium content was 1200 μg/kg, and in the Watarase river basin which is the lower reaches of Ashio copper mine in Gunma Prefecture, the maximum content was 312 μg/kg.

As to the difference of the cadmium content among rice varieties, it was likely that the cadmium content increases gradually in proportion to the length of growing period, namely ascending order being early rice, mid-season rice, late rice. But, this difference was smaller than the local difference. The relation between the type of grain and the cadmium content of the American rice was likewise indistinct, although the local difference was also remarkable in this case.

As for the distribution of cadmium in the rice grain, the rice bran, including the embryo bud and the outer part of endosperm, contained cadmium considerably as compared with the endosperm. But, this trend was indistinct, and cadmium distribution in the grain was rather homogeneous in comparison with other inorganic elements. In consequence, the ratio of content of cadmium to that of ash increases rapidly during the course of rice polishing.

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LITERATURE CITED

Baader E. W. 1951. Gesundheitsfürsorge und Arbeitsmedizin, Die Chronische Kadmiumvergiftung. Deut. med. Wochschr. 77: 484.

Friberg L. 1959. Chronic cadmium poisoning. Arch. Ind. Health 20: 401.

Katakura K., and Hatanaka C. 1959. Chemical analysis of the components of rice, which is suitable for saké brewing (I) Relationship between the mineral contents and the polishing rates of rice. J. Soc. Brewing, Japan. 54: 902.

Moritsugu M. 1964. Interferrence on colorimetric microdetermination of cadmium with dithizone. Japan Analyst 13: 64.

Moritsugu M., and Kobayashi J. 1962. Study on trace metals in bio materials (I) Geographical difference of metals contained in ayu (*Plecoglossus altivelis*). Ber. Ohara Inst. Landw. Biol. 11: 393.

Nicaud P., Lafitte A., Gros A., and Gautier J. P. 1942. Les l'esions osseuses de l'intoxication chronique par le cadmium. Aspects radiologique á type de syndrome de Milkman. Bul. et mim., Soc., méd hop. Paris 19: 259.

Nogyo-Gijutsu-Kyokai (Association of Agricultural Technicians) 1957. Nosakumotsu Hinshu Kaisetsu (Explanation on Varieties of Crops). (Tokyo).

Nogyo-Kairyo-Kyoku (Agricultural Improvement Bureau of Ministry) 1955. Ine Mugi Hinshu no Tokusei-Hyo (List on Characterization of Varieties of Rice, Wheat and Barley). (Ministry of Agriculture and Forestry, Tokyo)

Perry H. M., Jr., Tipton I. H., Schroeder H. A., Steiner R. L., and Cook M. J. 1961. Variation in the concentration of cadmium in human kidney as a function of age and geographic origin. J. Chron. Dis. 14: 259.

Piscator M. 1962. Proteinuria in chronic cadmium poisoning. Arch. Env. Health 4: 607.

Saltzman B. E. 1953. Colorimetric microdetermination of cadmium with dithizone. Anal. Chem. 25: 493.

Schroeder H. A., and Balassa J. J. 1961. Abnormal trace metals in man: Cadmium. J. Chron. Dis. 14: 236.